

SUBJECT: Performance of Communications  
Link Between Apollo CSM and  
DSN 210 Ft. Antenna at Goldstone  
Case 900

DATE: May 9, 1969

FROM: N. W. Schroeder

ABSTRACT

Circuit margins have been calculated for the communications link between a CSM using an omnidirectional antenna and a station of the Deep Space Network equipped with a 210 ft. diameter antenna. This link is a possible contingency link in event of failure of the CSM high-gain antenna.

In general for Block II CSMs, if the 5 dB on-axis gain of the omni antenna elements can be utilized (the CSM's attitude must be maintained to  $\pm$  30 degrees), high bit rate telemetry (51.2 kbps) can be transmitted alone with a bit error rate of about  $10^{-6}$ . For Apollo 10, however, the circuit margins calculated using the measured circuit losses of CSM 106 indicate that with the 5 dB antenna gain the margins for down voice, telemetry (51.2 kbps) and ranging are all positive or zero even when all three services are transmitted simultaneously from omnidirectional antenna element A.

The circuit margins and the estimated length of the period that the moon will be visible to the Goldstone station (12-13 hours) during the Apollo 10 mission indicate that the Goldstone station could significantly improve the support given a lunar orbiting CSM during this mission following a failure of the high gain antenna.

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COMMUNICATIONS LINK BETWEEN APOLLO CSM AND  
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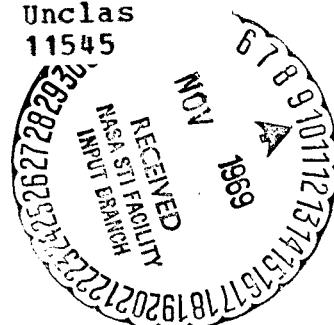
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MEMORANDUM FOR FILE

A CSM transmitting from an omnidirectional (CSM-Omni) antenna to an Earth station of the Deep Space Network (DSN) equipped with a 210 ft. diameter antenna is a possible contingency communications link if the High Gain Antenna on the CSM should fail. To determine the performance that could be expected from this link, circuit margins have been calculated and estimates have been made regarding the length of time that the CSM will be visible to the Goldstone DSN (210 ft.) while the vehicle is in lunar orbit. In addition to calculations using the specified values of the communications parameters, calculations were made using the measured values for CSM 106 (Apollo 10).

The circuit margin equations derived in reference 1 and the system parameters listed in Table III were used in the calculations. The results of the margin calculations are contained in Tables I and II. Figure 1, a plot of the telemetry (51.2 kbps) bit error rate vs. circuit margins is included for convenience in interpreting the telemetry margins presented.

Reference (3) contains plots of the antenna patterns for the omnidirectional elements. These plots indicate that the on-axis (gain 5 dB or greater) lobe for each of the antenna elements can be approximated by a square that is 60 degrees on a side and centered about each antenna element.

Results presented in Table I show the performance that can be expected in general from a block II CSM; results presented in Table II indicate the performance that is expected from CSM 106 (Apollo 10). Measured circuit losses for CSM 106 indicate that the best and worst performance is expected from CSM 106 omni antenna elements A and C respectively; therefore, the margins contained in Table II represent the bounds of the performance of this link for the Apollo 10 mission.

The length of the periods that the moon is visible to the Goldstone (210 ft.) station is a function of the declination of the moon. For an Apollo 10 launch of May 18, 1969, the declination of the moon while the CSM is in lunar orbit will result in expected moon visibility periods of

about 12 to 13 hours.<sup>1</sup> The orbiting CSM will be visible only about one half of this time, but even this is considered adequate for transmitting significant amounts of useful data if the 51.2 kbps telemetry bit rate is used. The 85 ft. diameter antenna MSFN stations can handle the low bit rate telemetry (1.6 kbs) from the CSM using its omni antenna elements but not the 51.2 kbps rate.

### Conclusions

1. If the CSM's attitude can be maintained to within  $\pm 30$  degrees (see reference 3), and Apollo 10 is launched on May 18, 1969, as scheduled, it is expected that the CSM S-Band transmissions from an omni antenna to the Goldstone (210 ft.) station would provide usable mission data for modes with phase modulation.
2. Circuit losses, applicable to Apollo 10, measured for each of the four CSM omni antenna elements are not identical; consequently, there is a range of circuit margins for this link. The best and worst margins are obtained using omni-A and omni-C, respectively.
3. Using the specified maximum circuit loss of 6.2 dB for the CSM (omni) and an on-axis antenna gain of + 5 dB, the circuit margins for the link are positive provided that each service (voice, TLM 51.2 kbps, and ranging) is transmitted separately.
4. Using the measured circuit losses applicable to Apollo 10, circuit margins are positive for down voice and ranging; bit error rates are expected to be less than  $10^{-6}$  and  $10^{-4}$  for transmissions from omni-A and C, respectively, even when voice, telemetry and ranging are transmitted simultaneously.

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2034-NWS-<sup>rkw</sup>  
eyd

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Attachments  
Tables 1-3  
Figure 1  
References

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<sup>1</sup>Estimate obtained from calculations by Mr. D. R. Anselmo

TABLE I

Circuit Margins Calculated for  
Communications from a  
CSM (Omni) to a 210 foot DSN

Station  
Using Specified Circuit Losses

<u>CSM Downlink Mode</u>	<u>Service</u>	Downlink USB Circuit Margin (Circuit Loss Specified = $-6.2$ DB) CSM Antenna Gain = $+5$ .DB
1.	Down Voice	-5.7 DB.
	TLM (51.2KBPS)	-8.9
2. w/uplink mode 6	Down Voice	-6.6
	TLM (51.2KBPS)	-9.8
	Ranging	+6.1
13.	TLM (51.2KBPS)	-5.1
		-.2 DB.
		-3.3
		-1.0
		-4.2
		+11.5
		+.5

These calculations apply to a lunar range of 215,000 nautical miles

TABLE II

Circuit Margins Calculated for Apollo 10 Communications  
 from the  
 CSM 106 (Omni) to a 210 foot DSN Station  
 Using Measured Circuit Losses

CSM Downlink Mode	Service	Downlink USB Circuit Margins
Transmitting from Omni A (Circuit Loss Measured = -1.78DB.) (Circuit Loss Measured = -3.6DB.)		
		<u>CSM Antenna Gain = +5.DB.</u>
		<u>CSM Antenna Gain = 0.DB.</u>
1.	Down Voice TLM (51.2KBPS)	-·7 DB. -3.9  +4.0 DB. +.8  -2.8 -6.0
2.	Down Voice TLM (51.2KBPS) Ranging	-1.5 -4.7 +10.9  +3.1 0.0 +15.8  -3.6 -6.8 +9.0
13.	TLM (51.2KBPS)	0.0  +4.8  -2.1  +3.1

These calculations apply to a lunar range of 215,000 nautical miles

TABLE III

USB System Parameters Used in  
Communications Margins  
Calculations for the CSM

<u>Parameter</u>	<u>DSN</u>	<u>CSM</u>	<u>Units</u>
	<u>Nominal</u>	<u>Worst</u>	
Receive Carrier (PM)	2287.5	2287.5	2106.406 MHz.
NSD Constant A	210.	210.	5800. Degrees Kelvin
NSD Constant B	3.05	3.05	.0275 X10.EXP15 Degrees/Watt
IF Bandwidth	4.8	5.3	4.6 MHz.
Video Bandwidth	-	-	1.7 MHz.
Ranging Channel Constant ( $R_0$ )	-	-	.633 None
Carrier Loop Bandwidth	50.	50.	800. Hz.
Pointing Loss	0.	0.	0. dB.
Polarization Loss	0.	0.	0. dB.
Transmit Power	10.	9.5	.0112 K watts
Antenna Gains			
- DSN (210')	60.5	-	- dB.*
- CSM (Omni) Specified	-	-	0. dB.
- CSM (Omni) Measured ** on axis			5 dB.

TABLE III (Continued)

<u>Parameter</u>	<u>Nominal</u>	<u>DSN</u>	<u>CSM</u>	<u>Nominal</u>	<u>Worst</u>	<u>CSM</u>	<u>Nominal</u>	<u>Worst</u>	<u>Units</u>
Transmit Circuit Loss									
- DSN (210')	0.	-	-	-	-	-	-	-	dB.
- CSM (Omni) Specified	-	-	-	-6.2	-	-6.2	-	-	dB.
Transmit Circuit Loss (Con.)									
- CSM (Omni-A) Measured ** For Apollo 10***	-	-	-	-1.78	-	-	-	-	dB. *
- CSM (Omni-C) Measured ** For Apollo 10***	-	-	-	-3.6	-	-	-	-	dB. *
Receive Circuit Loss									
- DSN	0.	0.	-	-	-	-	-	-	dB.
- CSM (Omni) Specified	-	-	-	-6.2	-	-6.2	-	-	dB.
- CSM (Omni-A) Measured ** For Apollo 10***	-	-	-	-2.2	-	-	-	-	dB. *
- CSM (Omni-C) Measured ** For Apollo 10***	-	-	-	-4.0	-	-	-	-	dB. *
Required Signal/Noise Ratios (PM)									
- Carrier	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	dB.
- Up Voice	-	-	-	10.0	10.0	10.0	10.0	10.0	dB.
- Up Data	-	-	-	10.0	10.0	10.0	10.0	10.0	dB.
- Down Voice w/Biomed	8.0	8.0	-	-	-	-	-	-	dB.

TABLE III (Continued)

Parameter	DSN		CSM		Units
	Nominal	Worst	Nominal	Worst	
-TLM (51.2KBPS)	8.5	8.5	-	-	dB. (BER = 10. EXP -6)
-Ranging	32.0	32.0	-	-	dB. (60 second acquisition time)
Predetection Bandwidths					
-Up Voice	-	-	22.0	24.2	KHz.
-Up Data	-	-	22.0	24.2	KHz.
-Down Voice w/Biomed	42.0	48.0	-	-	KHz.
-TLM (51.2KBPS)	180.	180.	-	-	KHz.
-Ranging	1.	1.	-	-	Hz.

Except for the items indicated by (\*), the system parameters listed above were taken from the MSC ISD Master Parameter list dated November 21, 1968.

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\*These parameters were provided by Hal Rosenberg, ISD, on April 30, 1969.

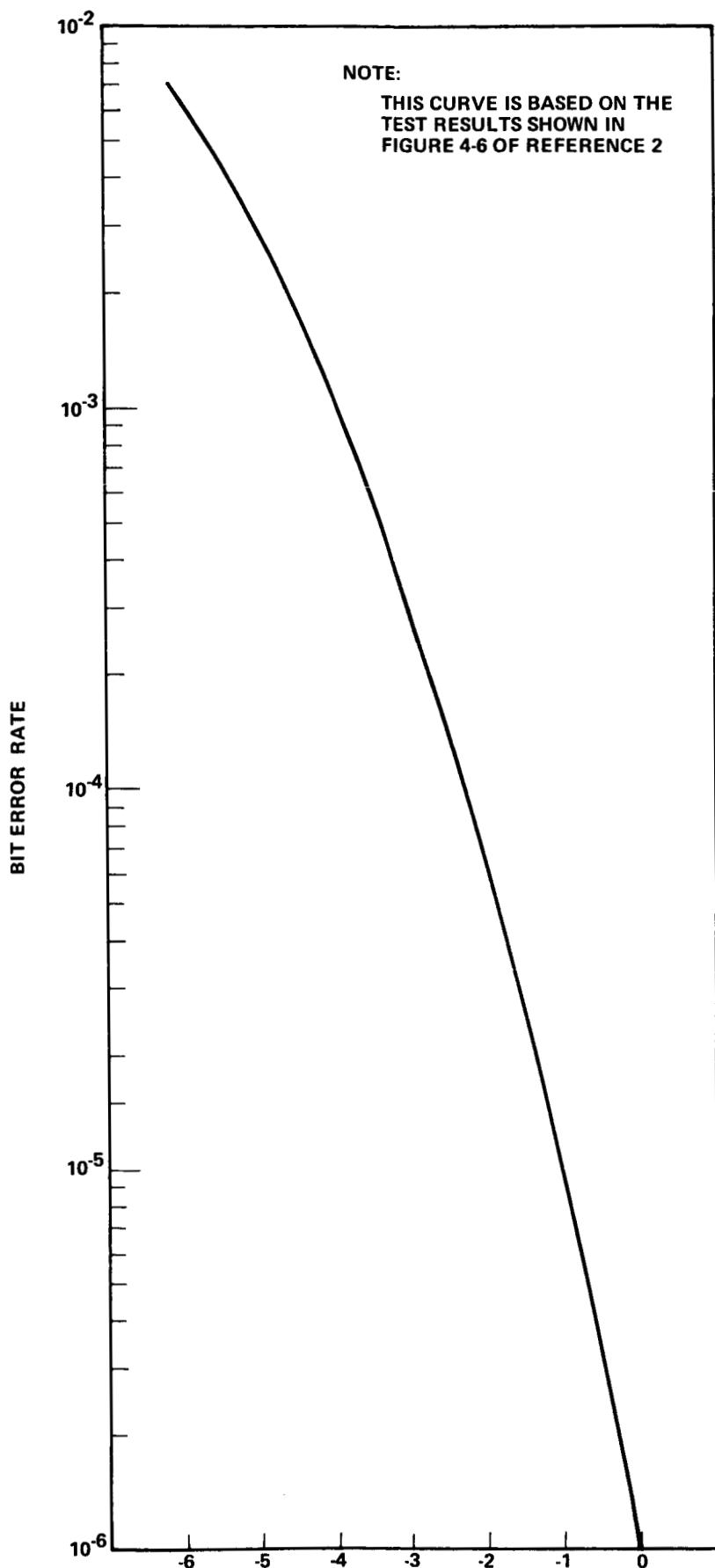


FIGURE 1 - 51.2 KBPS TLM CIRCUIT MARGIN IN DECIBELS

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REFERENCES

1. N. W. Schroeder, "Communications Margins for Apollo Unified S-Band Links with Phase Modulation," Bellcomm TM 68-2034-17, December 31, 1968.
2. "Apollo Block II Command Module Unified S-Band Manned Space Flight Network Systems Test Program's Data and Performance Summary," EB 68-3224 (u), Information Systems Division - Manned Spacecraft Center, Houston, Texas, November 8, 1968.
3. Jefferson F. Lindsey III, "Full Scale Block II Command and Service Module S-Band Omni Antenna Patterns," Manned Spacecraft Center Internal Note to No. 67EE-15 Project Apollo, June, 1967.

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